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Intentional replantation as an alternative treatment: survival analysis and key prognostic indicators

Nezahat Arzu Kayar[1], Damla Erkal[2*], Ayşenur Çohadar Kaya[1] and Kürşat Er[3]

Abstract

Background This retrospective cohort study aimed to evaluate the survival outcomes of intentional replantation (IR), an alternative endodontic treatment option when conventional and surgical approaches are not feasible, and to identify key prognostic indicators influencing tooth survival.

Methods A total of 55 teeth from 47 patients (36 females, 19 males) treated with IR were retrospectively analyzed. Clinical and radiographic data were collected over a mean follow-up period of 25.9 ± 18.7 months. Kaplan–Meier survival analysis with Log-rank tests, Fisher's Exact test, and Cox regression were used to assess survival time, categorical associations, and independent prognostic factors including gender, percussion and palpation sensitivity, periapical lesion status, and splint type.

Results The overall survival rate was 87.3% (48/55 teeth). The presence of preoperative periapical lesions significantly reduced survival ($p = 0.001$), while teeth stabilized with fiber-reinforced splints exhibited significantly better outcomes than those with rigid wire-composite splints ($p = 0.003$). Both factors remained independently associated with survival in Cox regression analysis.

Conclusions IR may represent a viable alternative option in selected cases, with splint type and preoperative periapical lesions emerging as factors associated with survival; however, findings should be interpreted considering the retrospective design and limited number of failure events.

Keywords Intentional replantation, Tooth Survival, Splint, Prognosis

Introduction

The primary objectives of root canal treatment (RCT) are to prevent or eliminate pulpal and periapical lesions and restore the periradicular tissues to a healthy state. Although nonsurgical RCT offers high long-term survival and success rates, enabling millions to retain their natural dentition, in some cases, healing may be incomplete, leading to the persistence of apical periodontitis [1]. Despite adequate RCT, post-treatment disease may persist due to reinfection by intraradicular microorganisms, extraradicular infections, cystic lesions or foreign body reactions. When nonsurgical root canal retreatment is

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impractical or unlikely to enhance treatment outcomes, surgical endodontics are the preferred approach [2].

Intentional replantation (IR) is considered an alternative treatment for inaccessible endodontic or resorptive lesions and serves as an alternative to endodontic surgery in cases where anatomical constraints, such as the maxillary sinus, mental nerve, inferior alveolar nerve, or thick buccal cortical plates in second molars, pose significant challenges [3]. IR, as described by Grossman et al. [4] entails the atraumatic extraction of a tooth, followed by inspection of the root surfaces, extra-alveolar endodontic management or repair, and subsequent reinsertion into the original socket at the same level. Previous meta-analytic studies [1, 5] have indicated that the survival rate of IR is considerably high, ranging from approximately 88% to 90%. In another systematic review by Pisano et al. [6] revealed that a survival rate of 86.7% has been estimated for IR, with no statistically significant difference observed between single-rooted and multi-rooted replanted teeth. The survival rate of single-rooted reimplanted teeth was 89.3%, whereas that of multi-rooted reimplanted teeth was 84%.

The clinical procedure of IR involves several pre-treatment, treatment, and post-treatment considerations. The pre-treatment steps include obtaining informed patient consent, conducting preoperative imaging (such as conventional radiographs and CBCT for three-dimensional details), and implementing a prophylactic regimen, which may involve systemic antibiotics based on the patient's medical condition. Additionally, maintaining oral hygiene and ensuring appropriate local anesthesia are essential [7].

During treatment, attention must be paid to atraumatic extraction of the tooth, minimizing damage to the root surface and surrounding tissues. In the case of IR, extra-alveolar manipulation should be minimized, with careful attention to maintaining tooth viability and reducing extra-alveolar time to less than 15 min. If necessary, root-end resection can be performed extraorally. Post-treatment care includes splinting, occlusal adjustments, and pharmacological therapy to manage the pain and prevent infection. RCT should be performed within 2-week, with restorative treatments generally initiated after 6- to 8-week [7].

This study aimed to present the survival rates for IR within our institution, along with documentation of instances exhibiting clinical and radiographic features indicative of both successful and unsuccessful outcomes.

Materials and methods

Study design and sample size

This retrospective cohort study was conducted in accordance with the PROBE 2023 guidelines for observational studies [8]. Clinical records of patients who underwent IR at a single academic center were retrospectively reviewed. A total of 55 teeth from 47 patients were included in the analysis. Most patients contributed a single tooth, whereas 8 patients contributed 2 teeth each. Some cases involved in this study are shown in Fig. 1. Clinical photographs were captured during treatment using a standard DSLR camera under operatory light without magnification.

As this was a retrospective cohort study, no a priori sample size calculation was performed. Instead, all eligible IR cases treated during the predefined study period were included consecutively to maximize available data. Given the limited number of failure events ($n=7$), the study was designed primarily to explore survival patterns and potential prognostic indicators rather than to test predefined effect sizes. Consequently, Cox regression estimates and subgroup comparisons should be interpreted cautiously and regarded as exploratory.

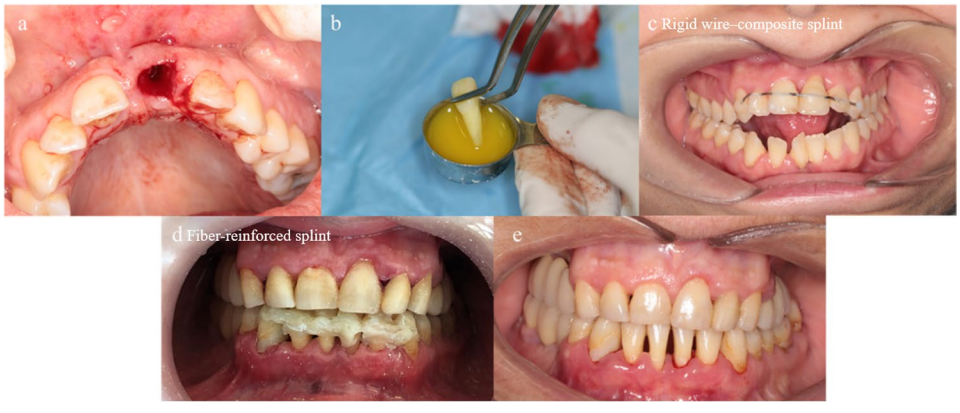


Fig. 1 Images from the cases included in our study ***a*** clinical view of the extraction site after tooth removal ***b*** extraoral treatment of the extracted tooth with tetracycline hydrochloride ***c*** postoperative intraoral image showing the wire-composite splint ***d*** another case showing fiber-reinforced splint ***e*** post-treatment healing and restoration of the reimplanted tooth at 12-month follow-up

Clinical evaluation and case selection

All cases included in this study were selected from patients aged between 15 and 80 years with no relevant medical history who were referred to the Department of Periodontology at the Faculty of Dentistry, Akdeniz University, Antalya, Turkiye. Primary outcome (tooth survival) was defined as retention of the replanted tooth in situ at the last follow-up (i.e., no extraction), regardless of radiographic healing status. Failure was defined as extraction of the replanted tooth for any reason during follow-up. Survival was selected as the primary endpoint because it is an objective and consistently retrievable outcome in retrospective clinical records. In contrast, strict biological success such as complete radiographic healing without ankylosis or external root resorption requires standardized imaging protocols and uniform longitudinal documentation, which were not consistently available in the present dataset. Therefore, radiographic healing, ankylosis, and external root resorption were recorded as secondary outcomes when available and interpreted descriptively rather than used to define the primary endpoint.

IR was considered strictly as an alternative treatment modality and was performed only when both conventional nonsurgical retreatment and endodontic microsurgery were deemed not feasible or associated with a high risk of iatrogenic complications. This approach is consistent with contemporary literature describing IR as an alternative in anatomically compromised cases or when orthograde and surgical strategies are unlikely to provide predictable outcomes [9, 10].

Conventional retreatment was regarded as not feasible in the presence of severe canal obliteration, high risk of perforation or ledge formation, intraradicular posts associated with a significant fracture risk during removal, or persistent pathology where further orthograde intervention was unlikely to improve prognosis. Microsurgery was considered not feasible when proximity to vital anatomical structures (e.g., inferior alveolar nerve, mental foramen, maxillary sinus), thick buccal cortical bone, or unfavorable posterior access significantly increased surgical risk [9]. The determination of non-feasibility was based on combined clinical and radiographic assessment, including periapical radiographs and CBCT imaging when available, to evaluate anatomical constraints, proximity to vital structures, and surgical accessibility. Treatment decisions were documented in patient records prior to extraction and were made within the framework of accepted endodontic standards of care.

The procedures were performed by residents under the supervision of a professor following a thorough explanation of the treatment protocol and potential complications, and after obtaining informed consent from the patients. Although the initial protocol emphasized anterior teeth with apical pathology, the expanded cohort included a broader range of tooth types, including premolars and lower incisors, based on anatomical feasibility and clinical indications. The inclusion of different tooth types was not based on intentional stratification but rather reflected real-world clinical decision-making. Intentional replantation was considered only in cases where conventional or surgical endodontic treatment was not feasible due to anatomical constraints, limited access, or procedural risks. Teeth were selected for IR if they exhibited radiographically confirmed periapical lesion and could not be managed effectively with conventional or surgical endodontic approaches owing to anatomical limitations. The exclusion criteria were systemic diseases known to impair healing, a history of head and neck radiotherapy, and pregnancy.

Preoperative clinical and radiographic assessment

After adequate medical and dental history review, the clinical examination involved evaluation of the entire mouth (teeth, tongue, gingiva, and mucosa), sensitivity tests, percussion, palpation, and probing depths. Panoramic and periapical radiographs were used as part of the radiographic examination.

A comprehensive medical and dental history review was conducted prior to the clinical examination. The clinical evaluation included a full oral assessment, including an examination of the teeth, tongue, gingiva, and oral mucosa. Diagnostic tests, including sensitivity testing, percussion, palpation, and periodontal probing depths, were recorded. Radiographic examination, consisting of panoramic and periapical radiographs, was performed to assess the extent of the pathology. All clinical and radiographic evaluations were conducted by a single experienced examiner.

Preoperative periapical lesions were recorded dichotomously as present or absent based on radiographic evidence of apical radiolucency associated with the treated tooth. Lesion size was not quantitatively measured because standardized radiographic measurements or 3D imaging were not consistently available in this retrospective dataset. Periapical radiographs constituted the primary imaging modality, whereas CBCT imaging was obtained only in selected cases for diagnostic purposes and was not available for all patients. Therefore, lesion severity could not be standardized across the cohort.

Endodontic status prior to extraction

In cases where canals were accessible, RCT was completed before extraction to avoid extraoral instrumentation. When canal access was not feasible, no extraoral RCT was performed to minimize extra-alveolar time.

Atraumatic extraction and socket management

During the replantation procedure, the teeth were gently extracted atraumatically using periotomes and appropriate forceps. Immediately following extraction, each tooth was placed on a sterilized, moistened sponge or wrapped in gauze soaked in sterile saline to preserve the viability of the periodontal ligament. The extraction socket was not instrumented or curetted, apart from the gentle removal of granulation tissue at its base. The inflamed gingival tissue was protected by avoiding mechanical contact with the socket walls to preserve the local architecture.

Extra-alveolar root surface management

The epithelial lining of the periodontal pocket was gently debrided using Gracey curettes, ensuring minimal trauma. Root surfaces were gently debrided to remove granulation tissue and calculus without damaging viable periodontal ligament fibers. A freshly prepared solution of tetracycline hydrochloride (100 mg/mL) (Boehringer Mannheim, Germany), filtered through a 0.45 µm Millipore filter (Millipore Corp., MA, USA), was applied to the root surfaces using sterile cotton pellets for 5 min. After conditioning, the roots were thoroughly rinsed with sterile saline to preserve PDL viability. Teeth were then reinserted into their original sockets, aiming for ideal anatomical positioning to minimize traumatic occlusion potentially caused by pathologic migration. In cases where apical granulation tissue prevented complete reinsertion, gentle degranulation of the apical socket was performed prior to replacement. No extraoral root-end resection or retrograde filling was performed as part of a protocol-driven approach aimed at minimizing extra-alveolar manipulation and preserving periodontal ligament vitality. In the present protocol, extraoral root surface conditioning with tetracycline hydrochloride was systematically performed as a biologically oriented strategy to reduce surface contamination and enhance periodontal ligament cell attachment. This adjunctive measure, together with strict limitation of extra-alveolar time, was intended to optimize healing conditions while avoiding additional apical manipulation [11]. This standardized approach was applied consistently across all cases, irrespective of preoperative periapical status.

Splinting protocol and postoperative management

For stabilization, a composite splint was applied interproximally and on the lingual surfaces only, with attention to esthetic concerns. Occlusion was carefully evaluated and adjusted in centric, protrusive, and lateral movements. The total extra-alveolar time was consistently maintained below 15 min, in accordance with the recommended protocols [9]. RCT was completed within 2-week of replantation.

The tooth was then replanted into its original socket. Stabilization was achieved using fiber-reinforced or rigid wire-composite splints (Fig. 1). In our cohort, splints were retained for approximately 2-3-week in all cases and removed at the first postoperative control visit. Splint duration did not differ between splint types and remained consistent throughout the study period. This short-term immobilization protocol was in line with ESE recommendations [7]. Over the course of the clinical series, splinting strategies gradually evolved in parallel with increasing clinical experience and the broader adoption of flexible splinting concepts in dental traumatology and periodontal healing. Consequently, fiber-reinforced splints were used more frequently in later cases, whereas rigid wire–composite splints were more commonly applied in earlier cases. Postoperatively, occlusal adjustments were performed to reduce the traumatic contacts. Endodontic treatment was completed within 2-week of replantation. Follow-up visits were scheduled at 3-, 6-, and 12-month, and annually thereafter for clinical and radiographic evaluations. Postoperative radiographic follow-up was not standardized at fixed intervals due to the retrospective design; instead, radiographs were obtained during routine clinical recall visits according to individual patient attendance patterns (Fig. 2).

Statistical analysis

The statistical analysis was performed using SPSS software (Version 26.0, IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard error (SE), while categorical variables were presented as frequency and percentage (%). The Kaplan-Meier method was used to compare survival times between groups, and the significance of differences was assessed using the Log-rank test. The relationships between categorical variables (e.g., gender, percussion, palpation, presence of periapical lesion, splint type) and prognosis were analyzed using Fisher's Exact test, considering sample size and cell distributions. The assumption of normality was examined with the Shapiro–Wilk test. Continuous variables that did not show normal distribution (e.g., age, probing depth) were evaluated in relation to prognosis using the Mann–Whitney U test. The proportional hazards assumption was assessed using log-minus-log survival plots. To determine the prognostic value of variables affecting survival time, a univariate Cox regression analysis was performed, and the results were reported as hazard ratio (HR) with 95% confidence intervals (CI). Because some patients contributed more than one tooth, potential patient-level clustering was considered. Because only 7 failure events occurred during follow-up, the number of events per variable (EPV) was insufficient to support reliable multivariable Cox modeling according to conventional recommendations

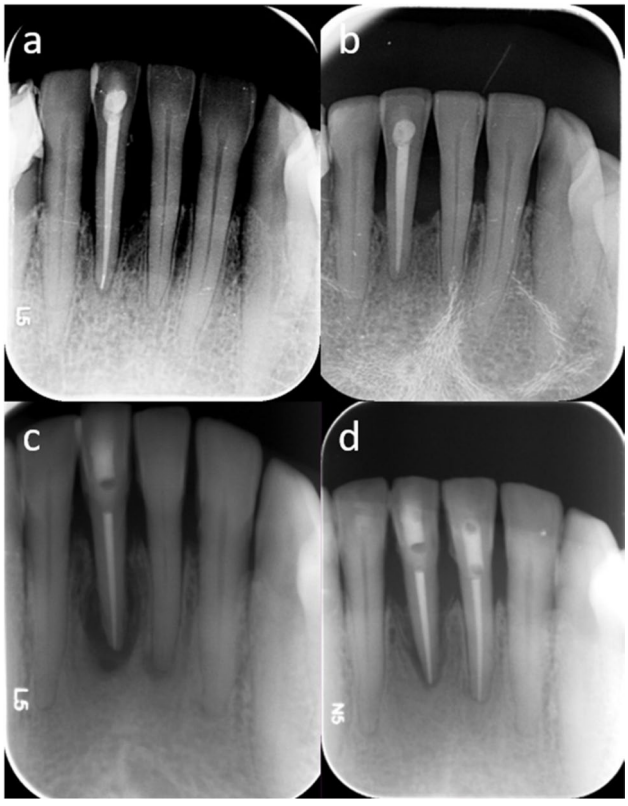


Fig. 2 Representative radiographic examples from 2 patients treated with IR ***a*** immediate periapical radiograph after endodontic treatment (case 1) ***b*** six-month follow-up radiograph of the same tooth ***c*** immediate periapical radiograph after endodontic treatment of another case ***d*** twelve-month follow-up radiograph

(≥ 10 events per variable). Therefore, only univariate Cox regression analyses were performed, and the results were interpreted as exploratory rather than confirmatory. A p-value of <0.05 was considered statistically significant for all tests. Tooth type and root morphology were recorded descriptively; however, they were not included as prognostic variables in survival analyses because of limited subgroup sizes and the small number of failure events, which could increase the risk of model overfitting.

Results

The Kaplan–Meier, Fisher's exact, and Cox regression analysis results for clinical and prognostic parameters are presented in Table 1. A total of 55 teeth from 47 patients (36 females, 19 males) were included with an overall survival rate of 87.3% (Fig. 3). Of the 55 replanted teeth, 48 (87.3%) survived (retained without extraction) and 7 (12.7%) failed (extracted) during follow-up. The patients' age ranged from 15- to 80-year, with a mean age of 43.6 ± 13.8 years. The mean follow-up period was 25.9 ± 26.0 months (median: 18 months; range: 1-144 months). The reported mean survival times should be interpreted with caution because they are derived from Kaplan-Meier estimates and may exceed the observed follow-up duration due to right censoring.

Most failures occurred within the first year of follow-up. There was no significant difference in survival time between male ($n = 19$, 34.5%; 135.4 ± 8.3 months) and female ($n = 36$, 65.5%; 67.6 ± 6.6 months) patients (Log-rank $p = 0.144$) (Fig. 2). Although male patients exhibited a slightly higher overall survival rate (89.5%) compared to females (86.1%), this difference was not statistically significant (Fisher's Exact $p = 0.401$).

Kaplan–Meier survival analysis revealed statistically significant differences in survival time according to both preoperative periapical lesion status and splint type. Teeth presenting with preoperative periapical lesions ($n = 13$, 23.6%) demonstrated a significantly shorter mean survival time (15.3 ± 3.4 months) compared with those without lesions ($n = 42$, 76.4%; 137.1 ± 4.8 months) (Log-rank $P < 0.001$) (Fig. 4). In categorical comparison, the overall survival rate was significantly lower in teeth with preoperative lesions (69.2%) than in those without lesions (92.9%) (Fisher's Exact $p = 0.006$).

Table 1 Kaplan–Meier, Fisher's Exact, and Univariate Cox regression analysis results for clinical and prognostic parameters

Variable	Group	Mean Survival Time ± SE	df	Log-rank *p*	Fisher's exact *p*	HR (95% CI)	*p* (Cox)
Gender	Male	135.429 ± 8.260	1	0.144	0.401	-	-
	Female	67.553 ± 6.552					
Percussion	Positive	144 ± 0.00	1	0.124	0.172	-	-
	Negative	116 ± 9.66					
Palpation	Positive	144 ± 0.00	1	0.385	0.577	-	-
	Negative	116 ± 9.66					
Periapical lesion	Present	15.337 ± 3.367	1	$P < 0.001$	0.006	-	-
	Absent	137.063 ± 4.785					
Splint Type	Fiber-reinforced	136.032 ± 5.510	1	$P < 0.001$	0.009	-	-
	Rigid-wire-composite	8.657 ± 1.200					
Probing Depth	-	-	-	-	0.043	0.44 (95% CI 0.23–0.85)	0.014
Age	-	-	-	-	0.931	1.01 (95% CI 0.96–1.07)	0.686

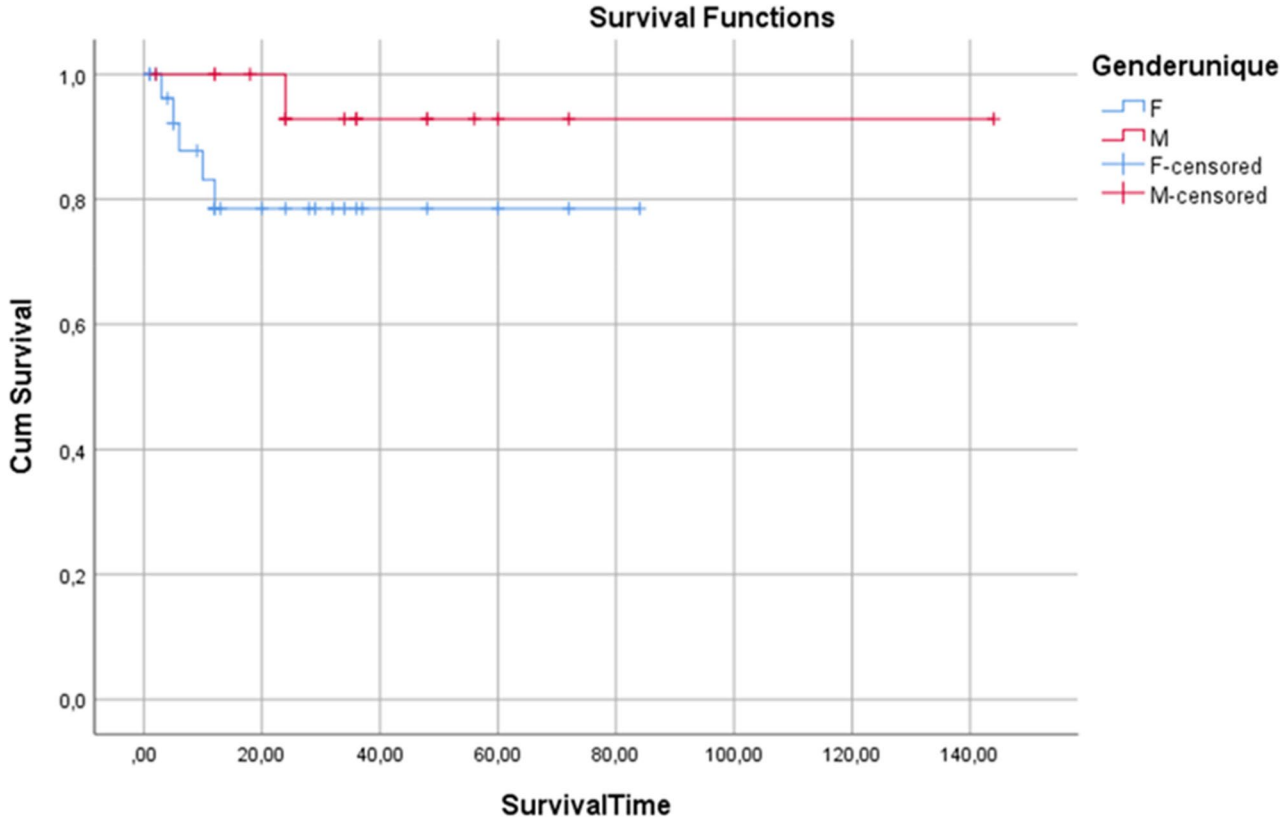


Fig. 3 Kaplan-Meier survival analysis curves comparing survival rates based on gender

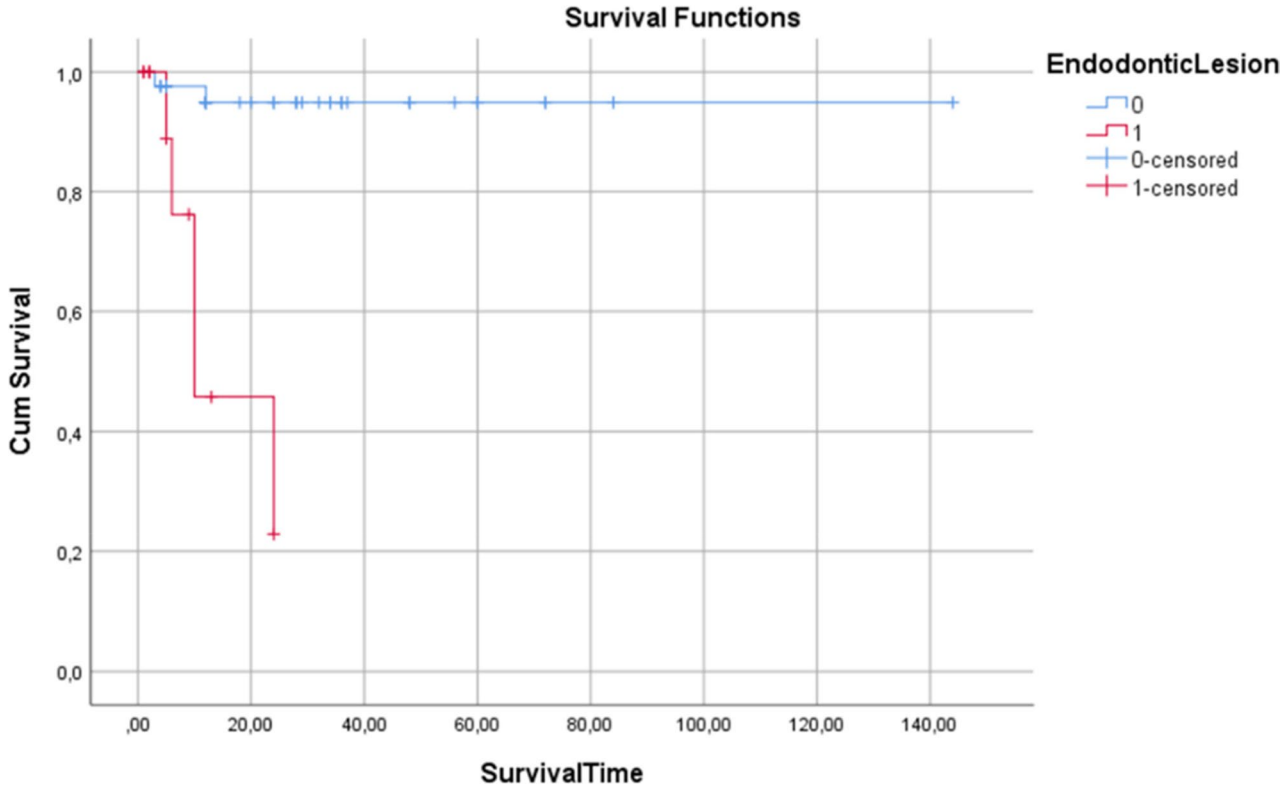


Fig. 4 Survival analysis based on preoperative periapical lesions

Regarding splint type, cases stabilized with fiber-reinforced splints ($n = 41$, 74.5%) exhibited a significantly longer mean survival time (136.0 ± 5.5 months) than those stabilized with rigid wire-composite splints ($n = 14$, 25.5%; 8.7 ± 1.2 months) (Log-rank $p < 0.001$). Consistently, the overall survival rate was higher in the fiber-reinforced group (95.1%) compared with the wire-composite group (57.1%) (Fisher's Exact $p = 0.009$). For preoperative percussion, the mean survival time was 144 ± 0.0 months in positive cases ($n = 14$, 25.5%) and 116 ± 9.7 months in negative cases ($n = 41$, 74.5%), showing no statistically significant difference between the groups (Log-rank $p = 0.124$). Although teeth exhibiting positive percussion tended to show lower overall survival (85.7% vs. 88.0%), this difference was not significant (Fisher's Exact $p = 0.172$). Similarly, preoperative palpation status did not significantly affect survival time (Log-rank $p = 0.385$) or survival rate (Fisher's Exact $p = 0.577$), suggesting that both findings may have limited prognostic value when considered independently in the context of IR.

According to the Mann–Whitney U test, probing depth showed a significant association with prognosis ($p = 0.043$), whereas age did not ($p = 0.931$). Probing depth was recorded in millimeters at baseline (preoperative clinical examination) and entered into the Cox model as a continuous variable. The event indicator in Cox regression was defined as tooth extraction (failure). Thus, hazard ratios (HRs) represent the relative change in the hazard of failure per 1-mm increase in probing depth (HR < 1 indicates a lower hazard of failure per mm increase). In the Cox regression analysis, probing depth remained a significant predictor of survival (HR = 0.44, 95% CI = 0.23–0.85, $p = 0.014$), whereas age did not show a significant effect (HR = 1.01, 95% CI = 0.96–1.07, $p = 0.686$).

In sensitivity analyses restricted to one tooth per patient ($n = 47$), the associations between survival and both preoperative periapical lesion status and splint type remained statistically significant (log-rank $P < 0.001$), and probing depth remained significant in univariate Cox regression, supporting the robustness of the main findings despite potential clustering.

These findings indicate that clinical and procedural parameters such as periapical lesion status and splint type were associated with survival outcomes in this cohort.

Discussion

IR has been recognized as a viable alternative treatment option when conventional endodontic procedures are unfeasible. This study aimed to evaluate the survival outcomes of patients with IR and identify prognostic factors influencing treatment success. The outcome assessment was based on objective criteria rather than subjective evaluation. A tooth was considered successful if it remained functional and asymptomatic in the oral cavity, whereas extraction for any reason constituted failure.

Our results demonstrated an overall survival rate of 87.3%, which is consistent with previously reported findings. Pisano et al. [6] in a systematic review, reported a survival rate of 86.7% for IR. Similarly, Hou et al. [12] in a case series, the authors found a cumulative survival rate of 88.2%. Furthermore, Torabinejad et al. [1] in another systematic review, reported an average survival rate of 88% across multiple studies. These findings collectively support the notion that IR, when executed with careful case selection and adherence to recommended protocols, can achieve clinical success rates comparable to those of conventional nonsurgical and surgical endodontic treatments. These findings confirm that IR, when performed under controlled conditions with strict attention to extra-alveolar time and PDL preservation, can yield survival rates comparable to other advanced endodontic procedures.

IR should primarily be considered in clinical situations where both orthograde retreatment and endodontic microsurgery are limited by anatomical or technical constraints. Such circumstances may include severe canal obliteration, intraradicular posts associated with a high risk of root fracture during removal, restricted surgical access due to thick buccal cortical bone, or proximity to vital anatomical structures such as the inferior alveolar nerve or maxillary sinus. Contemporary systematic reviews and position statements emphasize that IR may serve as a conservative tooth-preserving alternative when conventional or surgical endodontic approaches are unlikely to provide predictable outcomes and extraction would otherwise be indicated [1, 6, 7]. Careful case selection, atraumatic extraction, minimal extra-alveolar time, and preservation of periodontal ligament vitality remain critical determinants of treatment success [7].

In such circumstances, IR may provide a conservative tooth-preserving alternative, particularly when extraction and implant placement would otherwise be the only remaining option. Careful case selection, atraumatic extraction, and controlled extraoral handling remain essential determinants of outcome. Choi et al. [13] reported that age, gender, tooth type, and location did not significantly affect the survival of intentionally replanted teeth. In contrast, Javed et al. [2] found that female patients exhibited significantly better healing outcomes ($P < 0.05$). In the present study, although male patients exhibited a slightly higher survival proportion than female patients, the difference was not statistically significant ($P > 0.05$). This finding suggests that gender alone may not serve as a reliable predictor of treatment outcomes in IR. While biological factors such as hormonal profiles, bone density, and periodontal tissue

characteristics may influence healing dynamics, their precise roles in the context of IR remain to be elucidated. Further studies with larger and more diverse populations are necessary to determine whether gender-related physiological differences have a measurable impact on long-term prognosis.

While previous studies [6, 12–14] on IR have primarily focused on factors such as tooth type, splinting method, and periapical lesion presence, the impact of percussion sensitivity on survival outcomes has not been investigated extensively. Although our findings did not reveal a statistically significant association, the observed trend suggests that this clinical parameter may still be valuable in IR case selection. Further prospective studies with larger cohorts are needed to clarify the prognostic role of percussion sensitivity and to explore whether additional preoperative management strategies could enhance treatment outcomes in affected cases.

The presence of periapical lesions has been widely discussed as a potential negative prognostic factor for IR. In the present study, the presence of preoperative periapical lesions was found to be significantly associated with reduced survival (Pearson's chi-square, $p = 0.001$), consistent with prior research suggesting compromised healing potential in such cases. The absence of extraoral root-end resection or retrograde filling may have contributed to the reduced survival observed in teeth with preoperative periapical lesions. In such cases, residual apical infection or unresolved apical pathology could persist despite replantation, potentially compromising healing and long-term survival. Although root-end management has been advocated to enhance infection control in selected cases, the present study deliberately avoided additional extraoral procedures to minimize manipulation time and preserve periodontal ligament viability. This trade-off between apical infection control and periodontal ligament preservation underscores the complexity of outcome interpretation in IR. Therefore, lesion status in this cohort may reflect both baseline disease severity and the biological implications of the conservative extraoral protocol, rather than representing an intrinsic causal prognostic determinant. Similarly, previous case-based evidence has demonstrated that successful outcomes may still be achieved despite delayed endodontic intervention following tooth transplantation, provided that atraumatic extraction, strict aseptic conditions, and periodontal ligament preservation are ensured [15].

A critical point raised concerns the absence of routine extraoral root-end resection and retrograde filling in teeth presenting with apical periodontitis. Although IR has traditionally been associated with extraoral apical management, contemporary position statements do not mandate root-end resection in all cases. The European Society of Endodontology (ESE) indicates that root-end resection may be performed "if necessary," suggesting a case-dependent rather than obligatory approach [7]. Furthermore, long-term case series have demonstrated favorable outcomes without systematic apical resection, particularly when orthograde endodontic treatment had been previously completed and extraoral manipulation time was minimized. Hou et al. [12] reported an 88.2% survival rate over 5–12 years in periodontally compromised teeth managed with IR without routine apical resection, with minimal root resorption and absence of ankyloses. These findings suggest that infection control and periodontal ligament preservation, rather than universal apical resection, may represent the dominant biological determinants of healing. In the present study, extraoral time was strictly minimized, atraumatic handling was ensured, and orthograde disinfection had been previously completed, which may explain the favorable survival despite the absence of routine root-end surgery.

Root surface conditioning with tetracycline hydrochloride has been proposed to enhance periodontal ligament cell attachment and reduce surface contamination through its antimicrobial and collagen-exposing effects. Previous experimental and clinical studies have suggested that tetracycline treatment may promote periodontal healing by removing the smear layer and exposing collagen fibers, thereby facilitating fibroblast attachment and connective tissue reattachment [11].

These differences across studies underscore that survival and true healing are distinct outcomes; radiographic absence of lesions alone may not fully represent biological success. Torabinejad et al. [16] reported a weighted mean survival rate of 85.9% for IR in endodontically treated teeth with periapical lesion, with survival rates ranging from 62.2 to 98%. However, it is important to note that most studies, including ours, primarily assessed tooth survival, while true clinical success, defined as the absence of both radiographic and clinical signs of disease, varied widely between 33% and 95.3% [16]. The negative impact of periapical lesion on outcomes has also been reported in both surgical and nonsurgical RCTs, underscoring the importance of thorough infection control and promotion of favorable healing conditions in IR procedures [17]. In contrast, Lee et al. [18] reported no significant difference between the IR success rates in teeth with and without periapical lesions (66.7% vs. 72%, respectively), highlighting the multifactorial nature of healing in these cases. In this context, our reported survival rate reflects tooth retention rather than strict biological success. Accordingly, we prioritized survival as the primary endpoint and interpreted biological outcomes descriptively. It should be emphasized that radiographic healing was assessed based on available periapical radiographs obtained during routine follow-up rather than through a standardized scoring system such as the Periapical Index

(PAI), and CBCT imaging was not systematically performed at follow-up. Consequently, subtle apical changes, early replacement resorption, or localized ankylosis may have remained undetected. Furthermore, because imaging intervals were not standardized in this retrospective dataset, quantitative assessment of bone fill or lesion size reduction was not feasible. Therefore, while survival represents a reliable and objective outcome measure in retrospective clinical research, it does not fully capture the complexity of biological healing after IR.

Splinting plays a pivotal role in the stabilization and healing of replanted teeth. In this study, teeth splinted with fiber-reinforced materials exhibited significantly higher survival rates (p = 0.003) than those splinted with wire-composites. Several studies have reported successful IR outcomes without the use of splints [18–21], whereas the ESE currently recommends splinting for approximately 2-week in most cases [7]. In situations where primary stability is lacking, extended splinting periods of up to 6-week have been suggested [22]. The findings of this study align with current guidelines by emphasizing the potential clinical benefits of flexible splinting, although more robust data are needed to confirm its statistical impact on long-term success.

Fiber-reinforced splints are recommended because of their high flexibility, passive nature, aesthetic qualities, and compatibility with periodontal tissues. It has been reported that their minimally invasive and functional properties, especially following traumatic injuries, positively influence periodontal healing [23]. Similarly, Berthold et al. [24]. stated that composite splints reinforced with metal wires could negatively affect periodontal healing, as rigid splints may increase susceptibility to ankylosis and root resorption. The log-rank and Cox regression analyses demonstrated that preoperative lesion status and splint type were independently associated with survival; however, these findings should be interpreted cautiously given the retrospective design and limited number of failure events. These statistical findings suggest a potential association between infection control, biomechanical stabilization, and survival outcomes; however, causality cannot be inferred from this retrospective analysis.

Although IR demonstrated favorable survival in the present cohort, survival should not be equated with complete biological success. Previous studies have reported that inflammatory root resorption and ankylosis remain the most relevant long-term complications following IR [2, 25]. Even when early clinical and radiographic healing is achieved, progressive replacement resorption may develop over time and ultimately require extraction [26]. Therefore, delayed failure remains a recognized risk.

From a clinical standpoint, postoperative occlusal adjustment is sometimes performed during early healing to reduce functional loading; however, excessive occlusal reduction may compromise long-term structural prognosis and should be individualized. In addition, aesthetic alterations such as tooth discoloration may occur, particularly in previously endodontically treated teeth. While such changes do not affect survival per se, they may influence patient satisfaction, especially in anterior regions. Accordingly, patients should be informed that despite high reported survival rates, long-term risks include root resorption, ankylosis, aesthetic changes, and the potential need for eventual extraction.

This study has several limitations that should be considered when interpreting the findings. Although the overall sample size was adequate for survival analysis, certain subgroups—such as specific tooth types and splinting methods—were represented by relatively small numbers. Although this heterogeneity reflects real-world clinical indications for intentional replantation, it may limit the generalizability of tooth-type–specific conclusions. The limited number of failure events (n = 7) also prevented construction of a reliable multivariable Cox proportional hazards model; consequently, only univariate Cox analyses were performed and the hazard ratio estimates should be interpreted as exploratory rather than definitive prognostic indicators. In addition, although all procedures were performed under specialist supervision, operator variability inherent to resident-performed treatments may have influenced outcomes. Although the maximum follow-up reached 144-month, the mean follow-up duration of approximately 26-month may not have been sufficient to detect late complications such as root resorption or ankylosis. Further limitations are related to the retrospective design. Some patients contributed more than one tooth, introducing potential patient-level clustering; however, clustering-adjusted survival models (e.g., frailty models or robust variance estimation) could not be applied because of the limited number of failure events. Clinical mobility was not consistently recorded using a standardized scale, and radiographic healing or bone resorption could not be quantitatively assessed because follow-up imaging intervals were not standardized. Moreover, no extraoral root-end resection or retrograde filling was performed as part of the treatment protocol, which may have influenced outcomes, particularly in teeth with preoperative periapical lesions where residual apical infection cannot be excluded.

Conclusion

Within the limitations of this retrospective cohort study, IR demonstrated a high overall survival rate, supporting its role as a viable alternative treatment option when conventional or surgical endodontic approaches are not feasible. Preoperative periapical lesion status and splint type were significantly associated with survival; however, given the retrospective design and non-randomized treatment allocation, these findings should be interpreted as associative rather than causal. These findings suggest that IR success

may be influenced by a combination of biological viability, careful extra-alveolar management, and flexible short-term splinting rather than by isolated clinical parameters. Future prospective studies with larger cohorts, standardized protocols, and clustering-adjusted survival analyses are warranted to further refine prognostic models and establish evidence-based clinical guidelines for IR.

Abbreviations

IR	Intentional replantation
RCT	Root canal treatment
PDL	Periodontal ligament
CBCT	Cone-beam computed tomography

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
Conceptualization: N.A.K., K.E.Methodology: A.Ç.K., D.E.Formal analysis: N.A.K., D.E.Investigation: D.E., A.Ç.K.Writing – Original Draft: D.E., A.Ç.K.Writing – Review & Editing: N.A.K., K.E.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This retrospective study was conducted in accordance with the ethical standards of the Declaration of Helsinki. According to the Regulation on Clinical Researches on Humans published by the Turkish Ministry of Health (Official Gazette No. 28617, April 13, 2013), retrospective studies using anonymized clinical records without additional intervention do not require ethics committee approval. Therefore, the present study was exempt from formal ethics committee review. Informed consent was obtained from all patients for treatment and for the use of anonymized data for academic purposes.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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